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Analysis of the Pan-Tilt-Zoom Consistency of a Sony SNC-RZ30N Camera

by Nicholas Fung

ARL-MR-0721 **May 2009**

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14. ABSTRACT

Pan-tilt-zoom (PTZ) cameras are often the primary sensing equipment used in surveillance systems, because PTZ cameras allow a greater degree of flexibility in covering a large area with a limited number of cameras. Adapting these surveillance systems to remotely cue the PTZ camera using a networked computer station has increased their capability, but it has also increased their complexity. This report documents our efforts to measure the consistency of the SNC-RZ30N PTZ mechanism. Using a SNC-RZ30N Sony network camera created as a surveillance test bed at the U.S. Army Research Laboratory's Adelphi Laboratory Center, MD, we attempted to cue the cameras to a specific PTZ setting using a software interface; however, the device was not consistently accurate in transforming to the instructed PTZ setting.

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PTZ camera, camera consistency, SNC-RZ30N

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1. Introduction

Persistent surveillance is an important goal with many different applications. As part of the persistent surveillance test bed established at the U.S. Army Research Laboratory (ARL), Adelphi Laboratory Center, MD, four cameras were mounted on the roof and software was designed to connect these cameras to the local network system. The reliability of the persistent surveillance system is in large part dependent upon the accuracy and consistency of the camera control mechanisms.

An example application of the camera surveillance system is target identification. Target identification is the ability of the system to identify objects in the given scene and determine whether or not they are of interest. A simple algorithm for identification is to compare the current scene with a “typical” scene and note the difference in the images. The algorithm would be able to interpret the differences, infer objects, and determine if the objects are targets of interest. While the camera’s accuracy and consistency do not directly apply to identifying the target, it is important in locating a target relative to the camera’s position. Accurate pan, tilt, and zoom (PTZ) values allow for a target to be registered within a world model.

The goal of target tracking is to record movements or changes in an identified target. If the target is moving, the system should be able to follow and continually monitor the target. If the context dictates it, the system should notify a user or sound an alarm. Tracking a target requires accurate PTZ values. Accurate measurements allow users or software programs to better interpret movements of the target and anticipate tracking movements that the camera must take.

Camera calibration is the act of determining the camera’s external orientation and position in addition to its internal settings, such as the focal length. The benefit of deriving a camera’s external parameters is the ability to place the camera and the image within a world space. The accuracy of the camera’s PTZ functions is important for operating the camera without losing its position within the established space.

The effectiveness of these applications depends upon the ability to determine the current PTZ of the camera. Our goal in this report is to evaluate the camera’s ability to return to a specific PTZ orientation when starting from an arbitrary position. This data will provide an indication of how accurate and consistent the image processing algorithms can be implemented on these specific cameras.

2. Approach

2.1 Cameras

The four cameras of interest are Sony SNC-RZ30 models. Each of these cameras was mounted using a custom-built system to overhang from the roof of the Adelphi Laboratory Center, MD. An image of the mounted camera can be seen in figure 1. The Sony cameras are capable of a pan range from –170° to 170°. The tilt range of the camera is –90° to 25°. The cameras are capable of up to 25× optical zoom corresponding to values from 0 to 100. A value of 0 sets the camera at the lowest zoom setting with a 45° field of view, while a zoom value of 100 provides the highest zoom setting with a 2° field of view. The cameras also provide an additional 12× digital zoom, but this feature was not used in the experimentation.

Figure 1. Sony SNC-RZ30 camera with custom mount.

The cameras can record images at several resolutions. For this testing, we configured the cameras to output a stream at the highest resolution, 640x480. At the higher resolutions, each pixel corresponds to a smaller area, which will allow for a more precise measurement of individual points of interest.

2.2 Software

The Sony cameras each have a Web interface to control the device and view the incoming images. The interface uses a Java applet to provide a graphical user interface. The user interface could be used to capture images and save them on the local computer. The interface also provides the ability to pan, tilt, and zoom the camera. The pan and tilt are controlled through four buttons that a user can click with the mouse. The zoom is handled by a horizontal bar. The user can click along the bar to set the zoom. One limitation of this interface is that the pan, tilt, and zoom are inexact and a given PTZ setting cannot be reliably repeated.

To give more control over the positional settings, we created a custom program to control the cameras. The program has a simple design and leverages the network and software architecture of the Battlefield Information Processing internal network. The new control program takes in parameters from the user and sets the camera accordingly. For example, the user can cue the camera to pan to a value of 58. The advantage of such an interface is that the camera can consistently be cued to a specific positional setting.

2.3 Methodology

The testing method involved recording several images from the camera before and after altering the camera's positioning. We used the software interface to position the camera to specific PTZ values. The initial image recording was captured from this positional setting. We then cued the camera to another setting before cueing it back to the first setting. The second image recording is captured from this position. The more consistent the camera is in panning, tilting, and zooming to a given location, the more similar the two images will be.

To measure the consistency of the PTZ operation, we chose two easily distinguishable locations on the image. Figure 2 is a sample capture from one of the cameras. The image has been altered to highlight two points that can be used for measuring. In this instance, the chosen points are corners of parking spots. We measured the x and y coordinates of the selected points and compared them to subsequent image captures. The differences in the x and y measurements are an indication of the consistency of the pan and tilt positioning. The distance between the two selected points in the same image is directly correlated with the zoom of the camera. Thus, a difference in the distances between two images indicates inconsistencies with the zoom mechanic.

Figure 2. Sample camera image with brightened points of measurements.

Each data set taken consists of 20 sample images. The 20 images are broken into four different groups, which test the consistency of the pan operation, the tilt operation, the zoom operation, and an operation using pan, tilt, and zoom. Each group uses five images in an attempt to measure a specific movement by taking images before and after moving in a specific direction. The first image in a group is the starting image. The second image in the group is taken after moving the camera in one direction and back. The third image is taken after moving the camera in the opposite direction and back. The fourth and fifth images are taken after repeated movements. As an example, a group of images might be taken as follows:

1. Image 1 taken and stored.
2. Camera panned 30° and back.
3. Image 2 taken and stored.
4. Camera panned –30° and back.
5. Image 3 taken and stored.
6. Camera panned 30° and back.
7. Image 4 taken and stored.
8. Camera panned –30° and back.
9. Image 5 taken and stored.

The zoom is an important factor to consider when analyzing the data. At a higher zoom setting, each pixel represents a smaller angle than if the zoom were set lower. In other words, a standard deviation of 1.5 pixels with a zoom of 50 is not the same as a 1.5 pixel standard deviation with a zoom of 20. For this reason, the pixel difference values were converted to angles in order to measure the degree difference. In the previous example, the zoom of 50 yields a 0.037 horizontal degrees per pixel while the zoom of 20 corresponds to 0.057 horizontal degrees per pixel. In addition to being able to compare values from zoom settings, knowing the number of degrees off axis the camera is positioned is more directly applicable. The translation from pixel to degrees is accomplished via an approximated equation. The camera documentation specifies a viewing angle range of 2° to 45°. The maximum zoom value of 100 relates to a 2° viewing angle while the minimum zoom value of 0 corresponds to a 45° viewing angle. There are 640 pixels horizontally across the image and 480 pixels vertically. The camera zoom values of 0 to 100 are assumed to be on a linear scale. Thus, the following equations are formed:

$$\text{Pan Error (degrees)} = \text{Horizontal Error (pixels)} * \left(\frac{-43 * \text{zoom}}{100} + 45\right) \Big/ 640 \tag{1}$$

$$\text{Tilt Error (degrees)} = \text{Vertical Error (pixels)} * \left(\frac{-43 * \text{zoom}}{100} + 45\right) \Big/ 480 \tag{2}$$

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3. Data Analysis

A total of five sets of data were taken: one each from the four rooftop cameras and an additional set from a camera stationed on the southwest corner of the building with Internet protocol (IP) address of 172.18.130.210.

The first data set was taken by camera 172.18.130.210. The images for this set were taken with a pan value of –10, a tilt value of 20, and a zoom value of 60. The raw data can be seen in appendix A. The calculated average, standard deviation, and maximum deviation values broken up by pan, tilt, and zoom; the PTZ categories can be seen in appendix B. The data shows that the standard deviation of the change in pixel position is very small. The largest maximum deviation is four pixels in the horizontal direction and the largest standard deviation is 1.1695 pixels also in the horizontal direction. Using the approximate conversion discussed in the previous section, the maximum deviation translates to 0.12° and the standard deviation translates to 0.0351°.

The standard deviation and maximum deviation across all the data sets can be seen in figure 3. The standard deviations are all under 0.05° and the maximum deviations are under 0.3°. Statistically, about 95% of samples will lie within two standard deviations. Thus, future pan and tilt trials can be expected to be consistent within 0.1° about 95% of the time. Stated differently, successive pan and tilt movements will result in the same viewing angle within 0.1° with 95% certainty. The distance measurement is meant to evaluate the consistency of the zoom mechanic. The overall data shows that the standard deviation of the distance is 0.0268°. Similar to the previous assessment, this means that there is a 95% certainty that the zoom mechanic is consistent to within 0.06°.

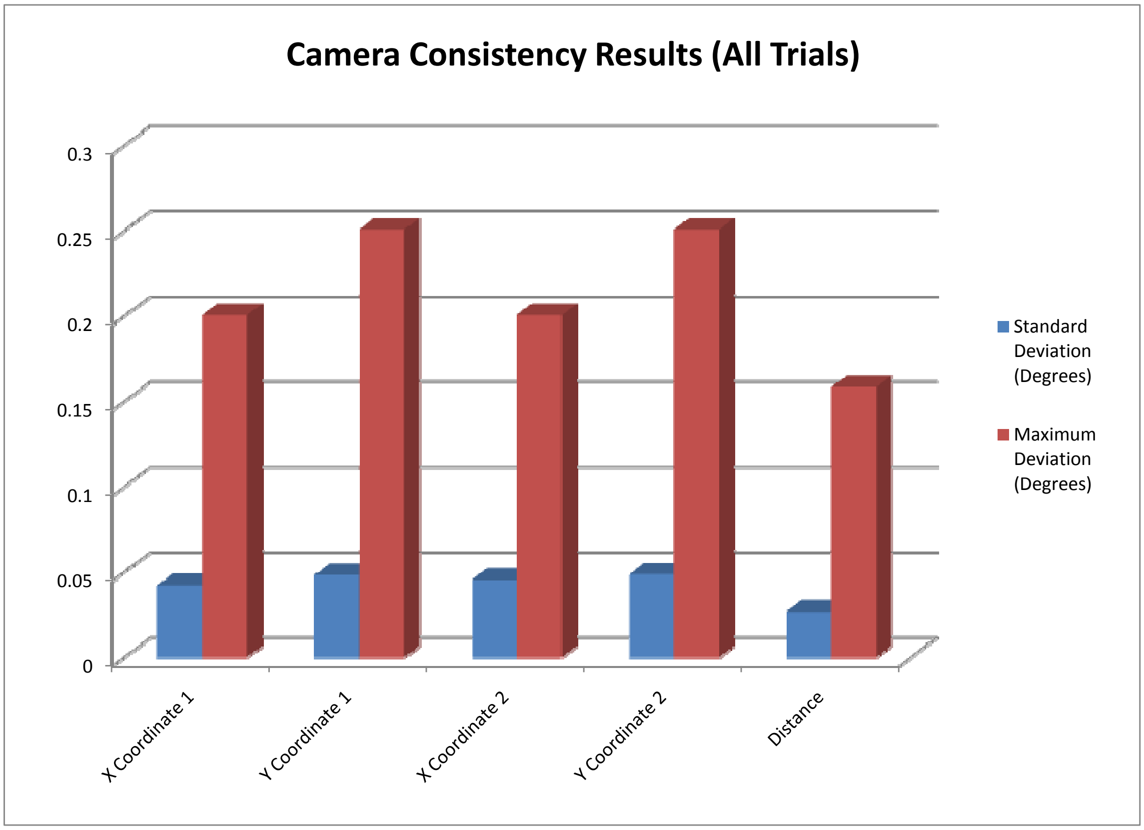

Figure 3. Maximum deviation and standard deviation across all trials.

A comparison of the standard deviations from different test sets can be seen in figure 4. The data sets in this chart are separated by trials that altered the pan, tilt, zoom, or all three mechanisms. Measuring the standard deviation over all three operations yields results from potential field usage of the device, when the operation may all be used to follow a target. The resulting data shows that there is not a large difference among the sets. All the standard deviations are less than 0.06° and larger than 0.02°. The largest differences occur in the *y* coordinates, where

changing the pan mechanism results in a smaller standard deviation than changing the zoom mechanism. Also, altering the zoom in both the zoom change data set and the PTZ change data set resulted in larger standard deviations than altering either the pan or tilt individually.

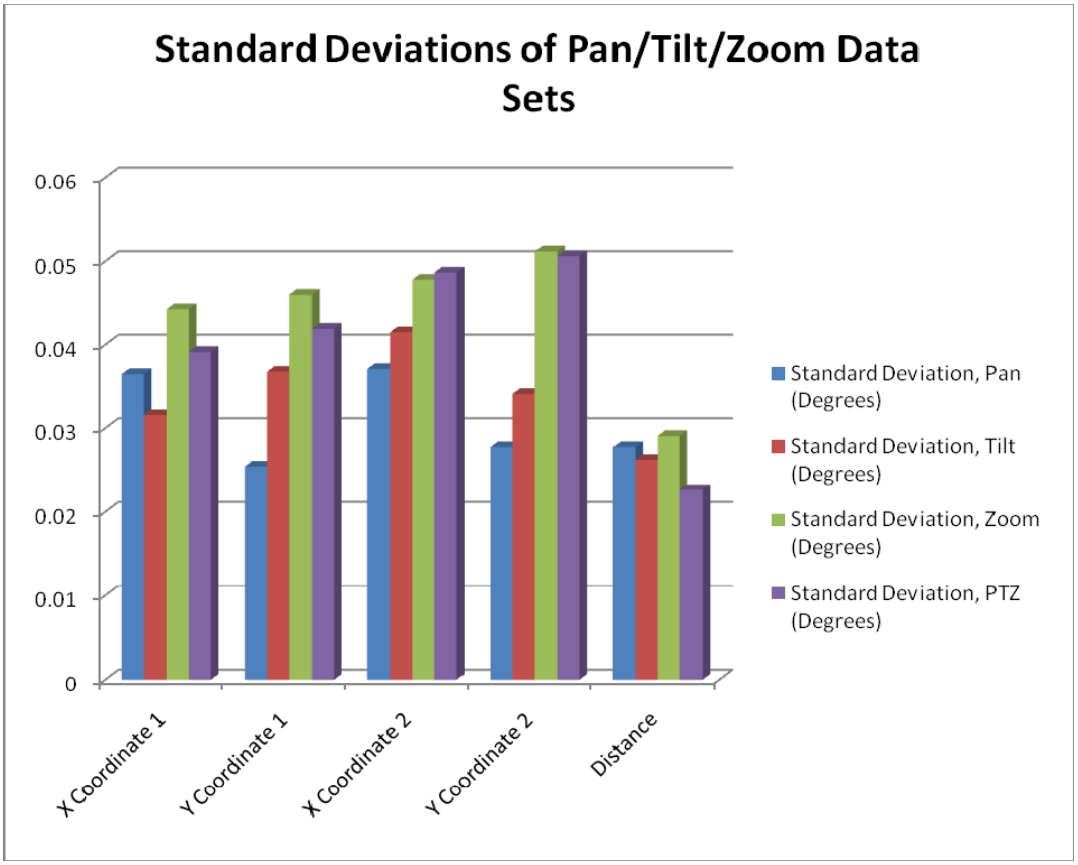

Figure 4. Standard deviations of pan, tilt, zoom, and PTZ data sets.

4. Conclusions

The inconsistencies found during this experimentation were meant to measure the ability of the PTZ mechanism of the cameras; however, several other factors could have contributed to these inconsistencies, including the camera installation physically moving due to wind or human error in the measurements.

The experiments data shows the Sony SNC-RZ30N cameras are consistent within 0.055° under pan, tilt, zoom, and PTZ operations. This value means that subsequent cues will have a 95% chance of viewing the same area to within 0.11°. Whether this accuracy is sufficient depends upon the application for which the camera is being used. For monitoring small objects at a large distance, this value may produce inaccurate results. For monitoring large objects at a close distance, this value may be sufficient.

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Appendix A. Raw Data Sets

Table A-1. Data Set 1, Camera 172.18.130.210.

172.18.130.210

Trial	Input Pan	Input Tilt	Input Zoom	Output Pan	Output Tilt	Output Zoom	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
1	–10	20	60	–9.889328	19.984894	59.997559	60	282	437	336	380.8477
2	10	20	60	9.889328	19.984894	59.997559					
3	–10	20	60	–9.889328	19.984894	59.997559	59	283	437	336	381.6975
4	0	20	60	0	19.984894	59.997559					
5	–10	20	60	–9.889328	19.984894	59.997559	59	282	436	336	380.8477
6	10	20	60	9.889328	19.984894	59.997559					
7	–10	20	60	–9.889328	19.984894	59.997559	60	282	438	337	381.9804
8	0	20	60	0	19.984894	59.997559					
9	–10	20	60	–9.889328	19.984894	59.997559	60	283	436	336	379.717
10	–10	40	60	–9.889328	39.969788	59.997559					
11	–10	20	60	–9.889328	19.984894	59.997559	60	283	437	336	380.7072
12	–10	0	60	–9.889328	0	59.997559					
13	–10	20	60	–9.889328	19.984894	59.997559	60	283	436	337	379.8579
14	–10	40	60	–9.889328	39.969788	59.997559					
15	–10	20	60	–9.889328	19.984894	59.997559	61	283	437	336	379.717
16	–10	0	60	–9.889328	0	59.997559					
17	–10	20	60	–9.889328	19.984894	59.997559	62	283	438	336	379.717
18	–10	20	20	–9.889328	19.984894	19.995117					
19	-10	20	60	–9.889328	19.984894	59.997559	58	283	434	336	379.717
20	–10	20	100	–9.889328	19.984894	100					
21	–-10	20	60	–9.889328	19.984894	59.997559	59	283	437	337	381.8377
22	–10	20	20	–9.889328	19.984894	19.995117					
23	–10	20	60	–9.889328	19.984894	59.997559	60	282	437	337	380.9908
24	–10	20	100	–9.889328	19.984894	100					
25	–10	20	60	–9.889328	19.984894	59.997559	59	283	436	336	380.7072
26	0	0	100	0	0	100					
27	–10	20	60	–9.889328	19.984894	59.997559	60	283	436	337	379.8579
28	10	40	20	9.889328	39.969788	19.995117					
29	–10	20	60	–9.889328	19.984894	59.997559	59	284	435	337	379.717
30	0	0	100	0	0	100					
31	–10	20	60	–9.889328	19.984894	59.997559	60	283	437	337	380.8477
32	10	40	20	9.889328	39.969788	19.995117					
33	–10	20	60	–9.889328	19.984894	59.997559	58	284	434	337	379.717
					Average		59.647	282.88	436.35	336.47	380.4989
					Standard Deviation		0.9963	0.6002	1.1695	0.5145	0.814234
					Maximum Deviation		4	2	4	1	2.263366

Table A-2. Data Set 2, Camera 172.18.130.210.

172.18.130.210

Trial	Input Pan	Input Tilt	Input Zoom	Output Pan	Output Tilt	Output Zoom	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
1	75	30	50	74.988144	29.977341	49.993896	155	241	431	195	279.8071
2	60	30	50	59.90514	29.977341	49.993896					
3	75	30	50	74.988144	29.977341	49.993896	154	240	432	196	281.4605
4	90	30	50	90	29.977341	49.993896					
5	75	30	50	74.988144	29.977341	49.993896	155	240	430	195	278.6575
6	60	30	50	59.90514	29.977341	49.993896					
7	75	30	50	74.988144	29.977341	49.993896	154	240	431	195	280.6314
8	90	30	50	90	29.977341	49.993896					
9	75	30	50	74.988144	29.977341	49.993896	154	240	431	195	280.6314
10	75	10	50	74.988144	9.992447	49.993896					
11	75	30	50	74.988144	29.977341	49.993896	154	240	431	195	280.6314
12	75	50	50	74.988144	49.962234	49.993896					
13	75	30	50	74.988144	29.977341	49.993896	154	241	430	195	279.8071
14	75	10	50	74.988144	9.992447	49.993896					
15	75	30	50	74.988144	29.977341	49.993896	154	240	431	195	280.6314
16	75	50	50	74.988144	49.962234	49.993896					
17	75	30	50	74.988144	29.977341	49.993896	154	241	432	195	281.7801
18	75	30	30	74.988144	29.909365	29.998779					
19	75	30	50	74.988144	29.977341	49.993896	154	240	431	195	280.6314
20	75	30	70	74.988144	29.977341	69.995117					
21	75	30	50	74.988144	29.909365	49.993896	155	243	431	197	279.8071
22	75	30	30	74.988144	29.977341	29.998779					
23	75	30	50	74.988144	29.909365	49.993896	155	243	431	198	279.6444
24	75	30	70	74.988144	29.977341	69.995117					
25	75	30	50	74.988144	29.909365	49.993896	155	243	431	198	279.6444
26	60	10	30	59.90514	9.992447	29.998779					
27	75	30	50	74.988144	29.977341	49.993896	154	240	431	195	280.6314
28	90	50	70	90	49.962234	69.995117					
29	75	30	50	74.988144	29.977341	49.993896	155	241	431	195	279.8071
30	60	10	30	59.90514	9.992447	29.998779					
31	75	30	50	74.988144	29.977341	49.993896	154	240	430	195	279.6444
32	90	50	70	90	49.962234	69.995117					
33	75	30	50	74.988144	29.977341	49.993896	154	240	431	195	280.6314
					Average		154.35	240.76	430.94	195.53	280.2635
					Standard Deviation		0.4926	1.1472	0.5557	1.0676	0.760043
					Maximum Deviation		1	3	2	3	3.12256

Table A-3. Data Set 3, Camera 172.18.130.211.

172.18.130.211

Trial	Input Pan	Input Tilt	Input Zoom	Output Pan	Output Tilt	Output Zoom	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
1	-60	35	30	-59.973284	34.803627	29.998779	280	338	340	184	165.2755
2	-80	35	30	-79.968376	34.803627	29.998779					
3	-60	35	30	-59.976284	34.803627	29.998779	280	337	340	184	164.3442
4	-40	35	30	-39.984188	34.803627	29.998779					
5	-60	35	30	-59.976284	34.803627	29.998779	279	336	340	183	164.7119
6	-80	35	30	-79.968376	34.803627	29.998779					
7	-60	35	30	-59.976284	34.803627	29.998779	280	337	340	183	165.2755
8	-40	35	30	-39.984188	34.803627	29.998779					
9	-60	35	30	-59.976284	34.803627	29.998779	281	337	339	184	163.6246
10	-60	10	30	-59.90514	9.992447	29.998779					
11	-60	35	30	-59.90514	34.939575	29.998779	281	334	341	180	165.2755
12	-60	60	30	-59.90514	59.954681	29.998779					
13	-60	35	30	-59.90514	34.939575	29.998779	283	333	342	182	162.1172
14	-60	10	30	-59.90514	9.992447	29.998779					
15	-60	35	30	-59.90514	34.939575	29.998779	281	333	340	180	163.9817
16	-60	60	30	-59.90514	59.954681	29.998779					
17	-60	35	30	-59.90514	34.939575	29.998779	282	334	340	180	164.56
18	-60	35	10	-59.976284	34.871601	9.997559					
19	-60	35	30	-59.976284	34.803627	29.998779	280	337	339	184	163.9817
20	-60	35	50	-59.976284	34.803627	49.993896					
21	-60	35	30	-59.976284	34.803627	29.998779	281	337	341	185	163.4136
22	-60	35	10	-59.976284	34.803627	9.997559					
23	-60	35	30	-59.976284	34.803627	29.998779	280	338	339	184	164.9151
24	-60	35	50	-59.976284	34.803627	49.993896					
25	-60	35	30	-59.976284	34.803627	29.998779	280	337	338	185	162.6899
26	-80	10	10	-79.897232	9.992447	9.997559					
27	-60	35	30	-59.90514	34.939575	29.998779	281	334	341	181	164.3442
28	-40	60	50	-39.913044	59.954681	49.993896					
29	-60	35	30	-59.90514	34.939575	29.998779	282	333	341	180	163.9817
30	-80	10	10	-79.897232	9.992447	9.997559					
31	-60	35	30	-59.90514	34.939575	29.998779	282	334	340	180	164.56
32	-40	60	50	-39.913044	59.954681	49.993896					
33	-60	35	30	-59.90514	34.939575	29.998779	282	333	341	180	163.9817
					Average		280.88	335.41	340.12	182.29	164.1785
					Standard Deviation		1.0537	1.9384	0.9926	1.9926	0.876609
					Maximum Deviation		4	5	4	5	3.158286

Table A-4. Data Set 4, Camera 172.18.130.212.

172.18.130.212

Trial	Input Pan	Input Tilt	Input Zoom	Output Pan	Output Tilt	Output Zoom	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
1	65	25	60	64.885376	24.94713	59.997559	234	211	493	432	340.4732
2	50	25	60	49.944664	24.94713	59.997559					
3	65	25	60	64.95652	24.94713	59.997559	236	211	496	432	341.2345
4	80	25	60	79.968376	24.94713	59.997559					
5	65	25	60	64.95652	24.94713	59.997559	237	212	496	433	340.4732
6	50	25	60	49.944664	24.94713	59.997559					
7	65	25	60	64.885376	24.94713	59.997559	233	211	492	432	340.4732
8	80	25	60	79.968376	24.94713	59.997559					
9	65	25	60	64.95652	24.94713	59.997559	237	211	496	433	341.1231
10	65	10	60	64.885376	9.992447	59.997559					
11	65	25	60	64.885376	24.94713	59.997559	233	211	492	433	341.1231
12	65	40	60	64.885376	39.969788	59.997559					
13	65	25	60	64.885376	24.94713	59.997559	234	211	493	433	341.1231
14	65	10	60	64.885376	9.992447	59.997559					
15	65	25	60	64.885376	24.94713	59.997559	233	212	493	433	341.2345
16	65	40	60	64.885376	39.969788	59.997559					
17	65	25	60	64.885376	24.94713	59.997559	234	212	493	433	340.4732
18	65	25	40	64.885376	24.94713	39.996338					
19	65	25	60	64.95652	24.94713	59.997559	237	212	496	433	340.4732
20	65	25	80	64.95652	24.94713	79.998779					
21	65	25	60	64.95652	24.94713	59.997559	237	211	497	432	341.2345
22	65	25	40	64.95652	24.94713	39.996338					
23	65	25	60	64.95652	24.94713	59.997559	237	212	497	434	341.883
24	65	25	80	64.95652	24.94713	79.998779					
25	65	25	60	64.95652	24.94713	59.997559	238	211	498	433	341.883
26	50	10	40	49.873516	9.992447	39.996338					
27	65	25	60	64.885376	24.94713	59.997559	234	212	494	434	341.883
28	80	40	80	79.897232	39.969788	79.998779					
29	65	25	60	64.885376	24.94713	59.997559	234	212	493	434	341.1231
30	50	10	40	49.873516	9.992447	39.996338					
31	65	25	60	64.885376	24.94713	59.997559	234	212	493	433	340.4732
32	80	40	80	79.897232	39.969788	79.998779					
33	65	25	60	64.885376	24.94713	59.997559	234	212	493	433	340.4732
					Average		235.06	211.53	494.41	432.94	341.0093
					Standard Deviation		1.7489	0.5145	1.9704	0.6587	0.530684
					Maximum Deviation		5	1	6	2	1.409821

Table A-5. Data Set 5, Camera 172.18.130.213.

172.18.130.213

Trial	Input Pan	Input Tilt	Input Zoom	Output Pan	Output Tilt	Output Zoom	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
1	40	15	60	39.913044	14.954682	59.997559	97	274	457	370	372.5802
2	20	15	60	19.992094	14.886707	59.997559					
3	40	15	60	39.984188	14.886707	59.997559	100	278	461	375	373.8048
4	60	15	60	59.976284	14.886707	59.997559					
5	40	15	60	39.984188	14.886707	59.997559	101	277	461	375	373.1005
6	20	15	60	19.992094	14.886707	59.997559					
7	40	15	60	39.984188	14.886707	59.997559	102	277	461	374	371.8736
8	60	15	60	59.90514	14.954682	59.997559					
9	40	15	60	39.984188	14.886707	59.997559	100	277	461	375	374.0655
10	40	5	60	39.913044	4.962235	59.997559					
11	40	15	60	39.913044	14.954682	59.997559	98	272	457	370	372.1357
12	40	25	60	39.913044	24.94713	59.997559					
13	40	15	60	39.913044	14.954682	59.997559	97	273	457	370	372.8391
14	40	5	60	39.913044	4.962235	59.997559					
15	40	15	60	39.913044	14.954682	59.997559	98	272	457	370	372.1357
16	40	25	60	39.913044	24.94713	59.997559					
17	40	15	60	39.913044	14.954682	59.997559	97	272	457	370	373.1005
18	40	15	40	39.984188	14.886707	39.996338					
19	40	15	60	39.984188	14.886707	59.997559	101	277	461	374	372.8391
20	40	15	80	39.984188	14.886707	79.998779					
21	40	15	60	39.984188	14.886707	59.997559	102	277	462	374	372.8391
22	40	15	40	39.984188	14.886707	39.996338					
23	40	15	60	39.984188	14.886707	59.997559	102	278	461	374	371.614
24	40	15	80	39.984188	14.886707	79.998779					
25	40	15	60	39.984188	14.886707	59.997559	102	277	462	375	373.1005
26	20	5	40	19.920948	4.962235	39.996338					
27	40	15	60	39.913044	14.954682	59.997559	98	274	457	370	371.614
28	60	25	80	59.90514	24.94713	79.998779					
29	40	15	60	39.913044	14.954682	59.997559	99	273	458	370	371.8736
30	20	5	40	19.920948	4.962235	39.996338					
31	40	15	60	39.913044	14.954682	59.997559	98	273	457	370	371.8736
32	60	25	80	59.90514	24.94713	79.998779					
33	40	15	60	39.913044	14.954682	59.997559	98	274	458	371	372.8391
					Average		99.412	275	459.12	372.18	372.6017
					Standard Deviation		1.9384	2.2913	2.1179	2.2977	0.730491
					Maximum Deviation		5	6	5	5	2.451455

Appendix B. Data Set Statistics

Table B-1. Data Set 1 Statistics, Camera 172.18.130.210.

	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
Pan Stats					
Average	59.6	282.4	436.8	336.2	381.02
Standard deviation	0.54772	0.5477	0.83666	0.4472	0.8858
Maximum deviation	1	1	2	1	2.2634
Tilt Stats					
Average	60.6	283	436.8	336.2	379.94
Standard deviation	0.89443	0	0.83666	0.4472	0.4314
Maximum deviation	2	0	2	1	0.9902
Zoom Stats					
Average	59.6	282.8	436.4	336.4	380.59
Standard deviation	1.51658	0.4472	1.51658	0.5477	0.9021
Maximum deviation	4	1	4	1	2.1207
Pan/Tilt/Zoom Stats					
Average	59.2	283.4	435.6	336.8	380.17
Standard deviation	0.83666	0.5477	1.14018	0.4472	0.5603
Maximum deviation	2	1	3	1	1.1307

Table B-2. Data Set 2 Statistics, Camera 172.18.130.210.

	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
Pan Stats					
Average	154.4	240.2	431	195.2	280.24
Standard deviation	0.54772	0.4472	0.70711	0.4472	1.0592
Maximum deviation	1	1	2	1	2.803
Tilt Stats					
Average	154	240.4	431	195	280.7
Standard deviation	0	0.5477	0.70711	0	0.7032
Maximum deviation	0	1	2	0	1.973
Zoom Stats					
Average	154.6	242	431.2	196.6	280.3
Standard deviation	0.54772	1.4142	0.44721	1.5166	0.9224
Maximum deviation	1	3	1	3	2.1356
Pan/Tilt/Zoom Stats					
Average	154.4	240.8	430.8	195.6	280.07
Standard deviation	0.54772	1.3038	0.44721	1.3416	0.5152
Maximum deviation	1	3	1	3	0.987

Table B-3. Data Set 3 Statistics, Camera 172.18.130.211.

	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
Pan Stats					
Average	280	337	339.8	183.6	164.65
Standard deviation	0.70711	0.7071	0.44721	0.5477	0.6949
Maximum deviation	2	2	1	1	1.651
Tilt Stats					
Average	281.6	334.2	340.4	181.2	163.91
Standard deviation	0.89443	1.6432	1.14018	1.7889	1.1819
Maximum deviation	2	4	3	4	3.1583
Zoom Stats					
Average	280.6	336.6	339.4	183.6	163.91
Standard deviation	0.89443	1.5166	1.14018	2.0736	0.8906
Maximum deviation	2	4	3	5	2.2252
Pan/Tilt/Zoom Stats					
Average	281.4	334.2	340.2	181.2	163.91
Standard deviation	0.89443	1.6432	1.30384	2.1679	0.7263
Maximum deviation	2	4	3	5	1.8701

Table B-4. Data Set 4 Statistics, Camera 172.18.130.212.

	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
Pan Stats					
Average	235.4	211.2	494.6	432.4	340.76
Standard deviation	1.81659	0.4472	1.94936	0.5477	0.3885
Maximum deviation	4	1	4	1	0.7613
Tilt Stats					
Average	234.2	211.4	493.4	433	341.02
Standard deviation	1.64317	0.5477	1.51658	0	0.3069
Maximum deviation	4	1	4	0	0.7613
Zoom Stats					
Average	236.6	211.6	496.2	433	341.19
Standard deviation	1.51658	0.5477	1.92354	0.7071	0.7054
Maximum deviation	4	1	5	2	1.4098
Pan/Tilt/Zoom Stats					
Average	234.8	211.8	494.2	433.4	341.17
Standard deviation	1.78885	0.4472	2.16795	0.5477	0.7053
Maximum deviation	4	1	5	1	1.4098

Table B-5. Data Set 5 Statistics, Camera 172.18.130.213.

	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
Pan Stats					
Average	100	276.6	460.2	373.8	373.08
Standard deviation	1.87083	1.5166	1.78885	2.1679	0.8947
Maximum deviation	5	4	4	5	2.1919
Tilt Stats					
Average	98	273.2	457.8	371	372.86
Standard deviation	1.22474	2.1679	1.78885	2.2361	0.8001
Maximum deviation	3	5	4	5	1.9298
Zoom Stats					
Average	100.8	276.2	460.6	373.4	372.7
Standard deviation	2.16795	2.3875	2.07364	1.9494	0.6202
Maximum deviation	5	6	5	5	1.4865
Pan/Tilt/Zoom Stats					
Average	99	274.2	458.4	371.2	372.26
Standard deviation	1.73205	1.6432	2.07364	2.1679	0.6629
Maximum deviation	4	4	5	5	1.4865

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Appendix C. Overall Statistics

Table C-1. Overall statistics in degrees.

	Point 1 x	Point 1 y	Point 2 x	Point 2 y	Distance
Overall Stats					
Standard deviation	0.042289	0.048306	0.045584	0.048654	0.026828
Maximum deviation	0.200625	0.250781	0.200625	0.250781	0.158408
Overall Pan Stats					
Standard deviation	0.036526	0.025446	0.037128	0.027756	0.027763
Maximum deviation	0.15	0.12	0.12	0.15	0.102922
Overall Tilt Stats					
Standard deviation	0.031546	0.036799	0.041483	0.034044	0.026251
Maximum deviation	0.12	0.200625	0.150469	0.200625	0.158408
Overall Zoom Stats					
Standard deviation	0.044201	0.045893	0.047804	0.051164	0.029074
Maximum deviation	0.15	0.200625	0.150469	0.250781	0.11161
Overall PTZ Stats					
Standard Deviation	0.03914	0.041887	0.048654	0.050577	0.02264
Maximum Deviation	0.12	0.200625	0.150469	0.250781	0.093799

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